Potential Applications of Wrought Magnesium Alloys for Passenger Vehicles

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As an initial project in the magnesium program at Argonne National Laboratory, the Center for Transportation Research has identified barriers to more widespread use of magnesium in automobiles. In the future, researchers will focus on applications of magnesium in cars and trucks, as well as production, alloying, forming, joining, and recycling issues.

Magnesium offers great potential to achieve lighter-weight automobiles by displacing steel, aluminum, and plastics. Available in almost unlimited supply from seawater, magnesium is 36% lighter than aluminum, and 78% lighter than iron, by volume. When alloyed, it has the highest strength-to-weight ratio of all the structural metals. Automakers' interest in magnesium is evidenced by a recent joint venture between Volkswagen and Israel's Dead Sea Works, which calls for a $350 million magnesium plant for producing auto parts.

The key factor blocking magnesium's widespread use is its price. Magnesium costs roughly three to six times as much as steel, and two to three times as much as aluminum, per pound; on a volume basis, the differential is less. Process R&D could significantly cut magnesium production costs. Reduced lifetime fuel costs and secondary weight savings, plus potentially lower fabrication and joining costs, could even push total lifecycle costs for magnesium parts below those for other materials.

Producing magnesium takes large amounts of electricity, but there is still a net energy saving in substituting it for heavier automotive materials. The lifetime energy consumption of Volvo's concept car, which used more than 100 pounds of magnesium in the wheels, chassis, and engine block, was estimated at less than 60% that of an equivalent-sized conventional auto. Meanwhile, less energy-intensive production processes are being investigated, and recycling at the end of the product's lifecycle could also save energy.

Because magnesium is easy to form, operations requiring several steps for steel can be done in a single step, so fabrication costs are lower. However, forming of magnesium sheet must be done at high temperatures (200-315°C), so machinery now in place for forming sheet steel cannot be used. Automakers shifting to magnesium sheet for major body parts would have to make significant new investments.

Magnesium is unfairly perceived as being highly flammable. Although safety precautions are required during machining, only very small chips and shavings can sustain combustion; larger pieces can even be flame-welded. Corrosion also has been a concern; parts can be protected with coatings, and improved alloys have been developed. As for impact resistance, magnesium structures can maintain crash safety standards.

Current production-model cars contain many small magnesium castings; some larger parts, such as entire dashboard panels made from a single casting, are in use or being prototyped. Wrought magnesium could be used in auto bodies as extrusions on primary structures, including spaceframes; magnesium castings are already being used for seat frames. Castings of magnesium are replacing iron, and even aluminum, in some powertrain housings and covers; it could eventually replace aluminum in the transmission's massive main housing. Wheels were one of the first applications for magnesium, and development of a competitive production process based on welded extruded and/or stamped components could lead to wide use. Most opportunities for magnesium use in the chassis require castings rather than extrusions, but extruded magnesium suspension links have been demonstrated on the lightweight experimental Ford "Synthesis."

Extensive use of magnesium could permit as much as a 40% reduction in mass, leading to a super-lightweight car. The economics of a magnesium-intensive body (perhaps including a lightweight plastic skin) appear quite attractive, and research on new production processes could significantly reduce material costs, as could development of economical hot-forming processes. Areas where additional research is needed include magnesium metal matrix composites and superplastic forming. When these issues are resolved, magnesium will be an attractive candidate for mass production in automotive structures.

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